RESEARCH IN AGRICULTURAL ENGINEERING, 1923.*

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The purpose of this report, as in previous similar reports, is to draw attention to and briefly discuss the more prominent features of agricultural engineering experimentation, investigation, and research completed, in progress, or in process of formulation during the year at the State agricultural colleges and experiment stations, certain other State, Federal, and private institutions, and certain foreign agricultural and engineering institutions.

No claim for completeness is made in this report, the intention being rather to survey the outstanding works with a view to bringing out lines for further study and of drawing special attention to what appear to be important lines of inquiry, neglected in certain studies which have been in progress for some time, and to proper starting points for other studies. Attention is also incidentally drawn in certain instances to some of the factors governing the evolution of research in agricultural engineering.

As usual, the work in agricultural engineering completed, in progress, or planned during the year included the following general subjects: Farm machinery, farm buildings and structures, drainage, irrigation, farm water supply and sewage disposal, land clearing, materials of construction, and miscellaneous.

FARM MACHINERY.

There is a record of at least 32 either specific or general farm machinery projects in operation at 13 stations in the States of Alabama, Michigan, Arkansas, Iowa, Nebraska, New York, Montana, West Virginia, Minnesota, Indiana, California, Wisconsin, and Missouri. Several of the stations still have projects under as general a head as farm machinery. It is believed, however, that the majority of these more general projects have undergone splitting processes into projects of a more specific nature and are practically inoperative, except in so far as they support such specific features.

Tractors.

The necessity for definite knowledge of tractor characteristics in relation to certain farming requirements and conditions has apparently caused the abandonment of much of the general tractor testing work in favor of certain more specific studies. Even the economic surveys of tractors have undergone somewhat of a change for the better, as indicated, for instance, by the work at the Alabama, Arkansas, West Virginia, and Montana stations in which analyses of failures have apparently brought out important points requiring serious study.

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The well-known study of tractor motor air cleaners at the California station apparently solved the problem of air cleaners for certain conditions in California. But to show how one study intelligently conducted grows into other broader studies, it became evident that more should be known about air cleaners to meet conditions in general. This led the Alabama station to study the problem from the viewpoint of its general applicability, and the conclusion was drawn that the logical starting point of such a study is the dust itself, since it is obviously the factor most vitally concerned. A study was then undertaken to learn something first of the fundamental principles governing the existence and movement of dust in an air cleaner and under engine intake conditions, to serve as a basis of methods for its maximum removal from the tractor air intake within a given range of partial vacua caused by intake suction and within a given range of amount and of physical, mechanical, and chemical composition of the dust. As far as can be learned, the tentative conclusion drawn by the station and by one of the larger private research agencies, working in cooperation, is that the air-floated dust causing trouble is of colloidal fineness, and that after so-called decolloidization or flocculation it is subject to control by known mechanical principles. The problem apparently now is to determine the factors governing the flocculation of air-floated dust under such conditions. While the above statement of progress results may not be absolutely accurate, it serves, on the other hand, to indicate an effective way of bringing agricultural engineering facts of universal application to light. The purpose of the work mentioned is evidently not to show what method of dust removal of those known and available is the best, but to indicate the principles which, when embodied in any air cleaner, will cause the maximum dust removal under the conditions imposed.

Preliminary studies of tractor characteristics have also indicated the importance of the problem involved in the traction of wheel tractors. Much experimental work has been done at great expense by several private commercial concerns with different kinds and types of tractor lugs. Such work has also been in progress at the Indiana, Michigan, Nebraska, and Alabama stations, according to the records, and probably at several other stations. In some cases, such as at the Indiana station, the work is a continuation of that conducted for some years. These works have served to indicate the complexity of the problem, but owing to the rather general failure to yield much universally applicable information, the Alabama station has undertaken a study of the fundamental factors influencing the traction of wheel tractors. It is quite significant to note that the main premise adopted is that traction is primarily a function of soil conditions and secondarily of the design of the tractor wheel, a fundamental conception apparently overlooked by other investigators. It is planned first to determine what soil factors govern and influence traction and then to determine the factors in tractor wheel design necessary to meet these soil factors.

The results from this project, while yet inconclusive, have so far indicated definite relations between traction and such soil factors as bearing value, resistance to penetration, and shearing strength. Hardness, cohesive, adhesive, frictional, and puddling properties, tenacity, and plasticity are other soil factors which have assumed considerable importance in this work. The results indicate further that the distribution of impulsive forces in

soils may be quite accurately determined. Compacting of soil slightly increases traction, the greatest increase being observed under quite wet conditions. Clay permits better traction than sand, except under extreme moisture conditions. The point of greatest efficiency or permissible slip is not constant, occurring later in dry loose soils than in moist compressed soils. An interesting feature of the experimental procedure in this project is that a close relationship has been established between the traction developed by a slowly rotating wheel when advancing and the force exerted by a stationary rotating wheel. The problem of traction in soil under such treatment has thus resolved itself primarily into one of soil dynamics and the influence thereof on traction. It may be noted in connection with this project that the Tractor Testing and Rating Committee states that until standard methods are available for computing and evaluating the soil factors governing traction, drawbar and other testing work for rating purposes will have no accurate basis for comparison.

Other tractor projects have been in operation at many of the stations, notably the Nebraska, Iowa, Montana, Minnesota, and California stations. The studies at the California station on the relation of side draft and tractor hitches and on the tendency of tractors to rise in front are particularly worthy of mention, and illustrate how effectively mechanics of engineering and sometimes the principles of pure science can be brought into such work, frequently as deciding factors.

As testing work pure and simple, the Nebraska tractor testing work apparently has little research standing. However, a careful analysis and intelligent interpretation of the large amount of data made available has yielded some new basic relations and principles of a general nature, which should influence the trend of further studies and perhaps aid in the ultimate standardization of tractor design. Some most interesting and important information on the interrelations of tractor rating, belt speeds, weight distribution, tractive efficiency, wheel slippage, piston displacement, and fuel and water consumption has been obtained in this analysis.

Another interesting but more general tractor study has been in progress at the experiment station at Lyallpur in the Punjab of India. The problem is one of cultivation rather than of tractors, but it has brought out the fact that of the makes of tractors at present available the wheel tractor is a better and cheaper type for plowing on hard firm soil, while the caterpillar type is the better for work on light sandy soils, or on any soils in small areas. Studies in Java indicate the futility of attempting the cultivation of rice and sugar cane soils with anything but cable-drawn outfits.

The work of the committee on tractor field machinery should have an important bearing on the future development of tractors, especially if conducted on the basis of an accurate preliminary knowledge of what each machine should do. The requirements of tractor field machines, collectively, form the main basis for studies of specific characteristics of farm tractors.

Tillage machinery.

Considerable work on tillage machinery has been conducted during the year, much of it continuing work which has been in progress for several years.

The majority of these studies have dealt with factors influencing the draft of plows and disk harrows, and almost without exception, the results have indicated the influence of the soil as a more or less unknown factor of primary importance. The well-known plow draft studies at the Iowa station, for instance, virtually eliminate the plow and constitute apparently a tacit admission of the primary importance of soil mechanics as the controlling factor.

Plow draft tests at the Nebraska, California, and Missouri stations, and disk harrow tests at the California, Nebraska, Missouri, and Iowa stations also have indicated the importance of a better preliminary knowledge of the ways in which soil properties influence the operation of tillage machinery.

With this in view, the California station is planning a project on the measurement of the mechanical characteristics of soils, the purpose evidently being to provide a rational basis for the development of tillage machines. The preliminary studies have indicated that shearing and compressive strengths and the factors governing friction between soil particles and metal surfaces are the characteristics of soils primarily influencing the operation of the metal parts of tillage machines through the soil. For the friction determinations, polished and flat or nearly flat circular rings, made of metals such as are used for the working parts of tillage implements, are to be placed upon flat spaces of soil, loaded with weights to simulate pressures actually met in practice and revolved about the central axis. The torques necessary to start and maintain motion through a small angle are to be measured and all other measurable data, such as density, moisture, humus,and silica contents, etc., of the soils are to be taken simultaneously. The shearing and compressive strengths of the soil are to be determined by measuring the forces required to cause the soils to yield when subjected to shearing and compressive stresses. Draft tests of plows are to be run simultaneously in the same soils, the purpose obviously being to simulate practical field conditions in the theoretical studies as nearly as possible. It is believed that if this study is so conducted as to bring out the factors and principles governing friction between metal surfaces and soils and the actual shearing and compressive resistances to the passage of tillage implements through the soil, much will have been accomplished toward providing a sound basis for the development of tillage machines.

The Alabama station is attempting to develop an even more fundamental conception of the influence of the soil factor on the operation of traction and tillage machines. On the basis that seed bed preparation and cultivation as well as traction are processes the efficiency of which depends upon meeting the mechanical properties of the soil with suitable equipment, it is considered desirable to establish universally applicable fundamental principles regarding soil dynamics so that, for instance, the results of a tillage study in California soils can be translated into terms of Alabama soils. The study has so far brought out that the important soil dynamic factors involved include resistance to penetration, shear, and pulverization, adhesive and cohesive properties, bearing strength, hardness, state of tilth, mechanical and mineralogical composition, specific gravity, humus content, absorptive power, frictional characteristics, and moisture limits for optimum tillage conditions. The studies apparently aim to evaluate these factors so that singly and in logical combinations they can all be con-

sidered in a manner commensurate with their importance in the development of tillage machinery design.

Several of the stations have found that this work cannot be effectively coupled as a whole with standard agronomic methods and classifications, due to the fact that the evaluation of many of the factors mentioned has been made by the agronomy people with an entirely different point of view from that of the agricultural engineer. This is taken to indicate the ultimate necessity for an entirely new classification of soils and their properties on the basis of engineering requirements. The studies at the U. S. Bureau of Standards on methods of measuring the plasticity of clays and by the British Society of Engineers on the physical properties of clays, with special reference to engineering requirements, are quite significant in this connection.

The California station also has devised a tentative method for measuring and standardizing the state of tilth of soil in connection with tillage studies, especially those on deep tillage implements. This method involves the use of different meshed screens placed one above the other, and yields data which, when graphically expressed, indicate the states of tilth of different soils and the tendencies of tillage operations in influencing tillage conditions.

There are at least 20 projects on different phases of tillage in operation at 12 different experiment stations. In nearly every case some phase of seed bed preparation is involved, the primary consideration being the influence of different methods of tillage upon the production of proper tilth conditions for certain specific crops. It would seem that many tillage studies might be effectively coupled with tillage machine studies, the resulting combined studies having for their object the development of tillage machines and methods which will produce definite required degrees of tilth in certain soils for certain specific crops or crop rotations. Obviously, a knowledge of what constitutes tilth of a certain desired degree in a soil is the first consideration. After this is known a knowledge of the other soil mechanics factors which govern the production of such a degree or state of tilth must inevitably follow. Thus a sound basis for the development of tillage machines and methods is provided.

The importance of consulting the soil specialist in this work is evident, owing to the further fact that studies such as, for instance, those being conducted at the Oklahoma station on the effect of lime and organic matter upon hardpan subsoils, at the Minnesota station on the first breaking of peat lands, and at the Rothamsted Experimental Station in England on the influence of liming of soils on their resistance to plowing, indicate that certain treatments tending to modify the physical and chemical composition of the soil may also tend to reduce its resisting influence to tillage to a minimum. It is easy to see wherein such processes if intelligently manipulated may materially influence the trend of tillage methods and ultimately of tillage machine design.

Lubrication.

Considerable study has been conducted during the year on the lubrication of internal-combustion engines, with particular reference to the re-

quirements of tractor and truck engines and stationary farm engines. The U. S. Bureau of Standards has been conducting perhaps the most fundamental studies on lubrication in its work on friction testing of lubricating oils and on the reclamation of used petroleum lubricating oils. The Department of Science and Industry of Great Britain has brought out the value of such solid lubricants as graphite, talc, soapstone, mica, flowers of sulphur, and white lead. Special attention has been given to the use of graphite in a deflocculated condition in oils for use in the lubricating of internal-combustion engine bearings and cylinders. The results as a whole indicate the desirability of using only a small amount of graphite in such oil, usually less than 0.35 per cent, but under such usage engines appear to start more easily and with greater freedom. The Royal Society of Great Britain has studied the characteristics of cylindrical journal lubrication at high values of the eccentricity to bring out methods of determining shaft wear in bearings and lubricant viscosity. Several of the experiment stations are considering different phases of tractor motor lubrication, among them being the Wisconsin, Texas, and California stations. Apparently the Wisconsin station is continuing its study of the influence of kerosene fuel on tractor lubrication, while the work at the California station is aimed primarily at the reclamation of used tractor crankcase oil.

Undoubtedly the problem of tractor motor lubrication is quite complicated and is far from being solved. For some reason it has been left mainly in the hands of manufacturers of lubricating oils. Thus engineers are placed in the doubtful position of adapting tractors to available lubricants rather than of specifying the oils required to meet specific conditions of operation of individual tractors. It would seem that more thought might profitably be given to the formulation of a plan of study of the subject to provide rational bases for specifying definite physical and chemical properties of lubricating oils for tractor motors for certain definite conditions of service.

Carburation.

Carburation is so intimately related to fuel characteristics, and fuels are so variable and uncertain as to uniformity of composition as to make it quite difficult to bring studies therein down to a very definite basis. The Engineering Experiment Station at Purdue University has been studying the effect of speed on mixture and other carburation requirements. The progress results have indicated that the change of speed of automotive engines does not affect the mixture ratios required to any marked degree when the temperatures are high enough for good carburation and the compression ratio is the same. On the other hand, one of our larger private institutions has shown that in actual practice it is well to depend as little as possible upon the cylinder heat and temperature to complete the vaporization of the fuel. These examples of apparently partially contradictory results indicate the complexity of the problem of carburation, and argue the importance of further preliminary study of the fundamental details of carburation as a basis for development.

Fuels and combustion.

Fuels and combustion have been subjects for considerable study during the year and apparently much progress has been made.

The Engineering Experiment Station at Purdue University has been studying internal-combustion engine characteristics under high compressions, using ordinary gasoline without detonation. The important fact was brought out that automotive engines designed to give a uniform cooling of the combustion chamber walls will permit the use of much higher compression ratios than those at present employed, with a consequent gain in power and economy.

Studies at Cornell University on the influence of proper timing of the ignition on the functioning of internal-combustion engines showed that spark advance is governed by the relation of the explosion time to the speed of rotation of the engine. It was found in this connection that one-half of the rise of pressure during combustion occurs substantially at three-fourths of the explosion time, thus indicating the numerical basis for the relations of explosion time, engine speed, and optimum spark advance. It was further found that fuel mixture density does not affect the explosion time and that dilution with exhaust gas is the factor requiring a spark advance as the engine is throttled. The slowing of combustion by dilution was found to be about proportional to the cube of the mass dilution ratio. Detonation apparently changed the combustion habit as if it produced an abnormal top to the combustion.

Studies conducted in Great Britain on the pressures developed in gaseous explosions indicated the importance of placing the spark in the center of the combustion chamber and of polishing the interior surfaces of the combustion chamber. Increasing the density of the mixture slightly increased the time of explosion and the ratio of the maximum absolute pressure to the initial pressure.

The studies of the U. S. Bureau of Standards on economic motor fuel volatility have shown that on the basis of amount of accomplishment per barrel of crude oil, the advantage among the fuels lies with that of lowest volatility when used under summer conditions. Studies under winter conditions with four fuels of different volatilities showed that at low speed and temperature more of a less volatile fuel was required to give a maximum power mixture than of a more volatile fuel. No large differences in fuel consumption of the high and low volatile fuels were observed in constant speed tests. The rate of crankcase dilution was greater with the less volatile fuels under all conditions and the circulating water temperature had the greatest single influence upon the rate of dilution.

Experiments with a farm engine conducted at the Carnegie Institute of Technology, using a fuel made by the catalytic oxidation of kerosene and a fuel of similar character made by the oxidation of gas oil, showed that the oxidized kerosene, having a lower boiling range than the raw materials, developed approximately the same power as ordinary kerosene, in spite of the fact that its thermal value is one-eighth less. It also showed lower detonation tendencies.

Studies at the Mellon Institute of Industrial Research on the use of acetone in composite engine fuels showed that acetone alone is an excellent fuel, easy to start with, does not freeze, and does not detonate under a pressure of 180 pounds per square inch. It can be mixed in all proportions with various other engine fuels and in small amounts minimizes the deposition of carbon and detonation of heavy hydrocarbon fuels.

Comparative engine tests by the U. S. Bureau of Mines with crude, acid refined, and silica gel refined motor benzols showed that crude motor benzol cannot be used satisfactorily in an internal-combustion engine, but that the acid refined or silica gel refined benzols develop no engine troubles and are satisfactory for use therein, provided the gum-forming constituents have been removed. Variation in the air fuel ratio had no definite influence upon the quantity of gummy deposits formed.

Tests by a private institution with a fleet of vehicles showed that motor benzol gave about 10 per cent better general results than gasoline.

Studies conducted in the French African colonies showed that peanut and sesame oils have a higher calorific value than palm and copra oils, and compare quite favorably in this respect with gasoline and benzol. Palm oil used in a tractor gave as good results on plowing as kerosene but at a somewhat higher fuel consumption. The possibilities of these cheap internal-combustion engine fuels for tropical climates appear quite promising.

Other farm machines.

Other farm machines besides tillage machines, tractors, and their accessories received a certain amount of attention during the year. The Wisconsin station continued its mowing machine investigations, indicating the power losses due to worn parts and bearings and dull knives.

The Canada Experimental Station found in studies of the combined reaper thresher in Saskatchewan that the cost of harvesting was reduced but that the degree of ripeness necessary to the satisfactory use of the combine resulted in a high percentage of soft wheat. While storage losses were low, the problem apparently is to perfect a practical method of bin curing. The development of an electrical method for this purpose would seem to have some promise.

The British Ministry of Agriculture has been engaged in studies of the mechanical thinning and harvesting of turnips. The preliminary studies of the objects to be accomplished and of available machines indicate the advantage of mechanical over hand labor methods, and show that the greatest possibility for development of such methods lies in the double or multi-row machines.

The Agricultural Experiment Station at Wageningen, Holland, has developed a method for balancing threshing drums and other high speed machinery, which consists in the use of one bearing as a center of rotation and another non-elastic bearing moving freely between two checks at a regulable distance apart. In case of an uneven distribution of the weight in the drum a clearly perceptible rattle occurs, and the quantity of overweight at any point due to uneven distribution is determined by measuring the centrifugal force produced by such overweight.

The machinery draft tests at the Missouri station have progressed into a study of the factors affecting the draft of wagons. It has been found that on roads of good brick, poor brick, cinders, wet gravel, and burned clay, the

wider tires give the heavier draft, while on all other roads the narrower tires give the heavier draft.

A private institution has shown in studies of motor truck wheels that the average wear of the tires mounted on metal wheels is about 13 per cent greater than that of those mounted on wood wheels. Studies of truck rear axles showed that, while the maximum shaft stresses are practically the same for semifloating and full floating axles, the shaft in the full floating axle can be made lighter and that a higher factor of safety should be employed in the semifloating axle, since the bending stresses are continually reversed.

The work of the committee on stationary farm engines of the American Society of Agricultural Engineers has indicated a decreasing demand for stationary farm engines during the past three years, and has emphasized the importance of a more intimate knowledge of the farm power requirements of stationary engines as a basis for their further development.

The New York Cornell station has an economic survey in operation of farm motor trucks in New York State. It is hoped that this survey will be carried out far enough to show specifically wherein motor trucks can be developed to better meet farming conditions. It is understood that work on the development of cotton spacing machinery is still in progress at the Arkansas station.

Interesting studies have been conducted by the dairy industries of the Dahme district in Germany on the comparative values of steam and central station electrical energy as sources of power in the dairy. The results of extensive studies indicate that electrical energy is in general the more expensive and that steam power plants accomplish on the average about 10 per cent more per unit of fuel used. Similar tests on the use of electricity and steam for threshing were much in favor of the latter, the total relative cost being only half that of electricity.

Studies by the Leather Belting Exchange to determine which side of an oak leather belt has the highest transmission capacity showed that under average service tensions the capacity of the flesh side averaged from 58 to 68 per cent of the capacity of the grain side.

The New York Geneva, Illinois, Connecticut Storrs, Texas, and South Dakota stations have projects on milking machines which, it is understood, are confined to the animal husbandry departments. It is believed in some such instances cooperation with the agricultural engineering departments in further work might be profitable, especially where it is desired to improve the efficiency of milking machines. The study at the Texas station, for instance, on the practicability of the milking machine, while productive of quite valuable results, has been conducted apparently from the viewpoint of the animal husbandman alone. While his viewpoint is the logical place to begin such work, it has apparently been attempted to meet his requirements with available methods and apparatus only. The results show, for instance, that with the mechanical milking apparatus available, it is possible to produce certified milk, but it requires much more attention and care than to

produce equally clean milk by hand. It would seem that cooperation with the engineer might take this work beyond the comparative into the investigational and developmental stages, with a view to increasing the efficiency of milking machines and ultimately of perfecting them.

A final example of farm machinery investigation which should interest agricultural engineers is the work at the Colorado station on methods of handling hay in the State. This work has so far apparently been limited to a consideration of methods and equipment for curing, stacking, and protecting alfalfa hay and seems to be in its preliminary stages. A problem evidently exists, and it is encouraging to note that work has been started with a consideration of the requirements of the thing most vitally concerned, the hay itself.

Obviously a clear, logical starting point is just as important in studies of farm machinery and accessories as a definite objective or a logical plan of procedure, and the progress in these respects in farm machinery studies is quite encouraging. In addition, it is evident that comparative tests of available machines can no longer be considered of any more than incidental or temporary importance in most cases of the development of a machine to accomplish a certain thing, and the importance of developing a machine to meet conditions rather than forcing conditions to meet the requirements of some machine available is even more plainly evident.

FARM STRUCTURES

The rather general activities on farm structures at many of the State colleges and experiment stations for several years have served the purpose of providing a broad general background and of bringing out the fact that in many instances the problems in farm structures requiring engineering treatment present conditions of a more or less special nature, offering opportunities for investigations immediately adapted to the situation.

It is significant to note that in 1922 there was a record of only 17 projects of study on farm structures at the experiment stations and that during the past year a record has been obtained of only 21 such projects at 9 stations in the States of Alabama, Arizona, Michigan, Iowa, Minnesota, Wisconsin, Kentucky, Indiana, and California, and at 1 insular station. This is taken to indicate a recognition on the part of many stations of the quite limited utility of broad general projects on the subject, and of efforts on the part of others to undertake the development of structures to meet certain specialized conditions.

General structures.

The Iowa station has apparently been the leader in this work. The silo, hog house, dairy barn, and farmyard equipment studies at the Iowa station are rather well known. The physical and chemical studies begun in 1912 on the relative durabilities of 35 brands of commercial 3-ply roofing have shown that the less durable materials are those having a high volatile content. A mineral surface of sand, gravel, asbestos, or mica materially

improves the durability of roofing. Exposure to the sun is apparently the most destructive influence and resinous knots in the sheeting are particularly destructive. These studies of commercial materials, while apparently comparative in nature, are significant in that they have been so conducted as to bring out the causes of deterioration of prepared roofing materials and of means for reducing the tendency to deteriorate under such causative influences.

Studies begun at the Iowa station in 1914 on making silo walls constructed of porous materials impervious have shown the effectiveness and superiority in this respect of bituminous material carefully applied to the surface by first sizing with a solution of the bitumen and then applying a hot layer. This treatment not only resists the action of the silage but has little tendency to peel or scale off. In addition, observations begun in 1910 at the station have indicated the effectiveness of double walls in preventing the freezing of water in masonry water tanks constructed on silos. Attention is drawn to these cases as illustrations of the fact that the right way to undertake such studies may frequently be the simplest way.

The studies of self-supporting barn roofs and of livestock feeding and management equipment at the Iowa station are so well known as to need no discussion. Similar work covering several phases of the subject is being conducted at the Alabama, Michigan, Minnesota, and Kentucky stations.

Heating and ventilation.

Considerable interest has been awakened recently in the heating and ventilation not only of dwellings and animal shelters but of crop storages. Projects on these subjects have been reported during the year from the Iowa, Minnesota, and Wisconsin stations, and a study on the heating and ventilation of homes is in operation at the Minnesota station.

The work on animal barn ventilation by the U. S. Department of Agriculture, perhaps the most comprehensive of its kind, is still in progress. It has established as a fundamental conception that the animal to be housed is the thing most vitally affected by heating and ventilation systems, whether artificial or natural, and that, therefore, the requirements of the animal as to heat and fresh air should be made the starting point for all such studies.

The Department has also shown that the factors influencing the desired temperatures and degrees of ventilation in animal shelters, in addition to the heat and fresh air requirements of the animals themselves, are insulation, tightness of construction, and amount of air space each animal is expected to heat. Studies conducted in this connection by a private institution resulted in the establishment of a mathematical basis for determining the thickness of insulation required to prevent sweating on cold surfaces under various conditions of temperature and humidity.

Studies conducted by the Department of Science and Industrial Research of Great Britain on the transmission of heat by radiation and convection, with particular reference to the influence of temperature, partitions, air

spaces, and nature of wall surfaces on radiation and natural convection within closed chambers, showed that the actual temperature of surfaces has a marked influence on the quantity of heat transmitted for a given temperature difference. Heat losses by convection increase more quickly than the first power of the temperature excess, a power of 5/4 seeming generally very satisfactory. Heat losses by convection are least in the horizontal position facing downward. A floor reduces the cooling of a vertical surface by about 4 per cent. The heat transfer by convection from unit area of surface across a closed vertical air space is independent of the height and width of the space. Studies by a German engineering experiment station on the heat conductivity of brick wall work and roof construction showed that such conductivity cannot be adequately expressed by a single factor. Studies of types of roof ventilators at the University of Minnesota indicated the superiority of the so-called rotary siphoning type.

Crop storage.

The development of structures for the storage of crops is quite a problem in some localities. The importance in such work of a careful preliminary consideration of the heat and ventilation requirements of the crop and of its behavior under storage conditions as a basis for the development of storage buildings cannot be too strongly emphasized.

Studies of potato warehouses at the Michigan station began with a consideration of the ventilation, temperature, and moisture requirements of the potato itself and of its behavior as regards rotting under storage, and proceeded ultimately to the development of warehouses with suitable ventilation systems for Michigan conditions. Successful storage was found to depend upon the maintenance of a dry atmosphere and a low temperature in the storage house, and of a movement of air through as well as around the potato pile. A temperature of from 33 to 38°F. was sufficiently low and bins not wider than 8 feet nor deeper than 10 feet, and kept some distance from the outside walls, permitted the proper ventilation.

Studies by the U. S. Department of Agriculture showed that all of 16 different varieties of sweet potatoes were susceptible to decay by one of the two organisms most commonly found under storage house conditions. Two of the varieties more resistant to this organism were susceptible to decay by the other one at temperatures of from 20 to 22°C. Studies at the California station on the storage of root crops showed that the factors influencing the keeping of such roots as mangels, sugar beets, rutabagas, and carrots in a dry condition are in order of importance, ventilation, date of storage, relation of storage space to ground surface, and presence or absence of straw before covering with dirt. Studies at the Arizona station brought out the importance of grading of sweet potatoes to a uniform size as a factor in the prevention of spoilage in adobe storehouses.

Studies of the storage of apples at the Iowa and Michigan stations indicated the importance of proper ventilation in the control of rots of some of the more important apple species. The studies at the latter station also showed that temperature is one of the most important factors in the keeping of apples. It was found that in air-cooled storages it makes

little difference whether a storage is partially underground or entirely above ground. At least 1 square foot of intake area in the ventilating system is necessary for each 700 cubic feet of storage capacity, while the outlet flues should have a combined area of about two-thirds of that of the intake area.

These studies indicate that the development of crop storages calls for intelligent cooperation between the agricultural engineer and the crops and crop disease specialists.

Farm dwellings.

The heat, ventilation, and moisture requirements of persons are the factors for primary consideration to provide a basis for the selection of heating and ventilating equipment and apparatus and proper materials of construction for farm dwellings. In this connection the University of Illinois, in studies of the humidity requirements of artificially heated residences, has shown that a room at 69°F. will be comfortable if the relative humidity is maintained at a value of from 35 to 45 per cent. A relative humidity of about 40 per cent is considered to be as high as it is practical to maintain in residences.

Studies at the Colorado station on the heat transmission of commercial wall board showed that the average coefficient of heat transmission varied from 0.73 B. t. u. per hour per square foot per degree Fahrenheit difference in temperature for actual thickness of beaver board to 1.01 for sheet rock wall board. Four other types of wall board had coefficients varying from 0.78 to 0.81. Interesting results have been obtained by the Department of Science and Industrial Research of Great Britain in studies on the efficiency of low temperature coke in domestic heating apparatus, especially sitting room and kitchen grates. Interesting studies conducted at the University of Minnesota have shown that the effect of pressure on hot water circulation in a small gravity hot water heating system is very slight.

DRAINAGE.

A vast amount of work, mostly of a service nature, has been done on the subject of drainage, and, with a few exceptions, very little work of a fundamental nature has apparently been undertaken. There is a record of 19 projects in drainage this year at 10 different experiment stations in the States of Illinois, Minnesota, Michigan, California, Mississippi, Montana, Oregon, North Carolina, Missouri, and Wisconsin. Some of these projects are quite general in nature, while others are more specific and are apparently attempting to establish standards for the spacing and depth of drains for particular conditions.

Little more than general information seems to exist as to what constitutes a well drained soil for a particular set of conditions, including crop, climate, etc., and, with a few exceptions, a consideration of the soil beyond rather vague empirical treatment has rarely been undertaken in this country as a basic consideration and logical starting point in drainage studies.

Certain foreign agricultural experiment stations have taken the view that the soil and the crop to be grown are the things most vitally concerned in drainage, and with this as a basis have undertaken to establish the principles governing the movement of water through soils of different physical and mechanical characteristics as a preliminary to the development of drainage methods. One study on the relation between soil properties and drainage has developed rather definite relations between permeability and such soil properties as clay content, calcium carbonate content, relative speed of sedimentation, specific surface, specific weight, and other lesser physical properties.

Steps in somewhat the same direction but of a more comprehensive nature are the plans at the North Carolina, Missouri, and Oregon stations to study the influence of the physical and chemical properties of the soil and of different soil treatments and crops on run-off. The work at the Wisconsin station on the drainage of peat soils has also developed into quite a fundamental study of a more or less similar nature, and involves a consideration of the subsoil as a factor in the drainage of peat. The Minnesota station is also engaged in studies of the drainage of peat soils, and the Oregon station has encoutered quite a problem in its investigations on the drainage and reclamation of alkali lands. In all these instances the importance of considering the soil first has been plainly evident.

Studies conducted at a Russian experiment station on the relation between temperature, barometric pressure, rainfall, and soil moisture showed that the ground water level rises as the soil temperature increases, especially when the upper soil layers are soaked with rain water. This is taken to indicate that the effect of temperature is due to its influence upon the air pressure in the upper layers of the soil, to the condensation of water vapor in the soil, and to changes in the capillary tension of the underground water. It was concluded that the immediate movement of the soil water level due to rainfall is caused by a change in the hydrostatic pressure of the soil gases at the ground water level, especially since the rapid infiltration of atmospheric precipitation to considerable depths was found to take place only under limited and exceptional conditions.

The interesting economic study by the Minnesota station of the cost of tile drainage in relation to the value of farm lands in Minnesota is worthy of consideration. This study brings out the fact that there is a limit to the practicability of drainage improvements under certain conditions, and it is believed that drainage studies should always consider this factor.

IRRIGATION.

Practically every State experiment station in the irrigated West has had projects on the subject of irrigation at one time or another, and there is a record for the year of at least 50 projects at 12 stations in the States of Washington, Oregon, California, Arizona, New Mexico, Nevada, Utah, Colorado, Idaho, Montana, Nebraska, and Wyoming. While some of these are apparently too indefinite to lay claim to a research status, many are planned along research lines and cover almost all phases of irrigation.

Some of the works at the California, Utah, Oregon, Nevada, Montana, and Washington stations and by the U. S. Department of Agriculture have brought out the fact that the most important factor concerned, the soil, has received relatively little study in its relation to irrigation methods and practices.

For instance, soil moisture movement studies at the Washington station made in relation to methods and amounts of application of irrigation water in border experiments showed that, generally speaking, most of the moisture was held in the first 4 feet. Only under exceptionally heavy irrigation did the soil samples show any pronounced increase in the fifth and sixth foot. Percolation tests showed the uniformity of lateral movement and indicated that 24 hours is sufficient for the irrigation moisture to meet the soil moisture vertically and to move 36 inches horizontally.

Studies at the Utah station on the water-holding capacity of irrigated soils showed that the amount of water absorbed by the soil when in need of irrigation varied from 0.5 inches of water to 1 foot of sand soil to 2.25 inches of water to 1 foot of clay loam soil. Further results showed that as a general rule soils can absorb from 0.5 to 1.5 inches of water to each foot of depth that needs moistening and that the actual capacity of a given soil depends upon its texture and structure.

Studies on the field moisture capacity and wilting point of soils at the Oregon station showed that the wilting point of soils is a valuable indicator in connection with the determination of the exact moisture content at which to irrigate. The wilting point varied more for different crops on a soil which was rather heavy in texture than on a soil of narrow moisture limits and marked the lower limit of usable water. Only the heavier classes of normal soils were capable of retaining as much as 2 inches of usable water in the surface acre-foot. The coarsest soils used for irrigation retained only half an inch per foot of depth, while peat retained from 3 to 4 inches per acre-foot. The irrigation requirement was greater for soils of coarse texture and low humus content and was largely due to unavoidable waste in connection with light frequent irrigation.

Studies by the U. S. Department of Agriculture on the storage of water in soil and its utilization by spring wheat showed that on land producing a crop each year, differences in cultural methods are not sufficient to cause major differences in the depth to which water is stored and from which it is recovered. Alternate fallowing and cropping resulted, on the average, in the utilization of a somewhat greater volume of soil. Available water when present in the soil was removed with about the same degree of frequency from each of the first 4 feet. These results are taken to indicate that the utilization of a large soil mass is not essential to a high yield, this depending more upon the maintenance of a constant supply of available moisture at a depth at which it can be easily obtained.

Studies at the California station on the losses of moisture from cultivated and uncultivated uncropped sandy, dense clay, silt, sandy loam, and clay loam soils containing gravel showed that the differences between the losses of moisture from cultivated and from uncultivated soils are so small as to be well within the limits of probable error. No less of moisture by

lateral movement was detected, and there was no significant difference in the distribution of moisture to a depth of 20 inches in the cultivated and uncultivated soils. These results were confirmed in the laboratory, and the studies as a whole showed that the loss of moisture from cultivated and uncultivated soils was confined almost entirely to the surface foot. Field and laboratory studies showed that the moisture lost directly by evaporation from the surface of the soil is negligible as compared to the water required for the support of a crop.

Studies at the Utah station on the effectiveness of mulches in preserving soil moisture showed that an effective mulch of 1 inch of straw is capable of preserving 60 per cent more moisture in the soil than is retained without mulching. Straw was the most efficient mulch material used, followed in order by hay, grass, wood shavings, and manure. It was found that an efficient mulch must consist of material which does not absorb or retain moisture readily and which forms practically no capillary system in itself. The effectiveness of mulching and cultivation increased with their depths, and the rate of evaporation from soils under mulch varied according to their moisture contents. The finer soils lost the most water. While cultivation and mulching saved moisture, the evapo-transpiration ratio was least with no mulch or cultivation. Fall plowing preserved more moisture than spring plowing, and the results are taken to indicate that in the dry farm regions shallower cultivation is preferable to the deeper cultivation.

The Punjab, India, Department of Agriculture has devised a new method for the determination of the average diameter of a soil particle as an important preliminary consideration in determining the permeability of a particular soil for air and water. The results of studies indicate that variation in the pore space does not affect the average diameter of the particle. A slight difference up to 3 or 4 per cent in the percentage of clay in two soils materially changed the value for the average diameter when permeability was the important factor concerned. This is opposed to the results indicated by ordinary mechanical analyses and emphasizes the importance of studies of soil hydraulics.

Duty of water studies have been in operation at the Utah, California, Nevada, Oregon, Arizona, and Montana stations during the year. The work at the Utah station, which has been in operation for seven years, on sandy loam and fine sandy loam soils began with a consideration of the average permeabilities of the soils and their maximum capacities for absorbing and retaining water. On this basis the studies were extended to show the proper use of water on such crops as beets, potatoes, and alfalfa on these soils.

Studies of methods of increasing the duty of irrigation water by the Oregon station showed that the duty of water was nearly doubled by proper rotation and crops and the use of manure, and that the existence of a richer and better balanced nutrient solution in the soil resulted in a lower water requirement. The results are taken to indicate that the duty of irrigation water will vary somewhat with the season and with anything which affects the evaporation, percolation, or transpiration of soil moisture. These two sets of studies furnish ample proof of the importance of the soil as a

basic factor in any study of duty of water. This point has also been brought out quite strikingly in studies on the irrigation of sugar cane at the experiment station of the Hawaiian Sugar Planters' Association and by general irrigation studies at the Universidad Nacional de La Plata. The work at the latter institution is planned to include a quite detailed preliminary study of soil hydraulics.

The loss of irrigation water by deep percolation and seepage is also closely connected with soil properties. Studies at the Montana station showed that losses of irrigation water from small grain and alfalfa soils varied from 0 to 45 per cent of the amount applied, the average loss being from 22 to 23 per cent. The losses depended upon the head, the method of irrigation, the handling of the water, and the condition of the soil. Seepage losses from laterals averaged about 30 per cent of the total amount of water entering the laterals.

Studies by the Colorado station on the return of seepage water indicated the magnitude and complexity of the problem and showed that in two large irrigation districts the ratio of the seepage return is about the same as the ratio of the gross duty of water.

The reclamation of alkali soils is closely related to irrigation, but the problem involved is largely one of soil physics and chemistry. There are at least 14 projects on alkali soils at 8 stations in the States of California, Utah, Wyoming, New Mexico, Oregon, Idaho, Arizona, and New Jersey, most of them being aimed at methods either for removing the alkalinity or reducing its effect. The work at the New Jersey stations on the use of sulphur on impervious alkali soils is quite significant in that it shows the oxidizing power of such soils for sulphur and the influence of the resultant sulphuric acid in coagulating the soil cementing colloids, thus destroying impermeability and permitting leaching operations.

The alkali investigations at the California station have also shown the neutralizing influence of sulphuric acid, gypsum, elemental sulphur, ferrous sulphate, and alum on black alkali and have indicated the value of simple leaching with and without gypsum treatment on irrigated vineyard soils. These studies have also indicated the tolerance limits of certain irrigated crops to different alkali salts.

Studies by the U. S. Department of Agriculture demonstrated the effectiveness of manure alone or in combination with gypsum, sulphur, or acid phosphate for the reclamation of alkali soils on different irrigation projects where the soil has become hard and impervious after each irrigation.

Studies at the Wellcome Tropical Research Laboratories at Khartum on the relation between the moisture equivalent of heavy soils and alkalinity showed that treatment of such soils with dilute solutions of flocculating salts such as calcium sulphate, ammonium nitrate, or ammonium sulphate reduced the moisture equivalent, while alkalis such as sodium carbonate increased it up to a certain point and then decreased it.

The U. /S. Department of Agriculture and the Colorado station have been the leaders in work on the measurement of irrigation water. The studies of weirs, current meters, and Venturi flumes at the Colorado station have been productive of quite useful information. The California, Utah, Idaho, and Montana stations have also done some quite useful work on water measurement devices and methods.

Pump irrigation is also gradually increasing in importance, and work has been in progress during the year on the subject at the Nebraska, Arizona, Montana, and Utah stations.

FARM WATER SUPPLY AND SEWAGE DISPOSAL

There is a record of 12 projects in farm sewage disposal at 8 experiment stations in the States of Montana, Minnesota, Missouri, New Jersey, Illinois, New York, Michigan, and California, and at Kansas Agricultural College and Pennsylvania State College. The importance of a consideration of this subject from its logical beginning through its scientific contacts to an ultimately practical solution for definite groups and classes of conditions is strongly emphasized by some of these projects.

A careful consideration of all the factors involved, with particular reference to the object to be accomplished by sewage disposal measures seems to indicate the importance of first studying, analyzing, and classifying the conditions to be met by such measures. This was done in a tentative and general way by the writer, but in a manner sufficiently comprehensive to show the possibilities of such a procedure (see Amer. Soc. Agr. Engin. Trans., 11(1917),pp. 67-76). The work of the New York Cornell station and Pennsylvania State College and of several of the State departments of health have shown that such a procedure is well worthy of consideration as a preliminary to undertaking studies on farm sewage disposal.

If the conditions to be met in a locality fall within a class or group requiring the absolute purification of the sewage, then the objective is clearly evident. From that point on the thing most vitally affected is the sewage itself, and ways and means of bringing about its purification must be made to conform to the requirements for its transformation from the raw to the purified states. Obviously then, the services of the chemist and bacteriologist should be enlisted by the engineer in determining the nature of the processes involved in such transformation, and the absorptive and oxidizing properties of soils should also receive consideration.

With at least some of these objects in view, the Illinois station has undertaken a cooperative project designed to bring out some of the relations between sewage tank dimensions and the chemical and biological changes taking place therein. The New Jersey stations are continuing their study of sewage filter biology and the Montana station is still engaged in a study of the factors governing the operation of septic and Imhoff tanks. The Kansas Agricultural College is also developing a fundamental study of the subject, based largely upon the principles outlined above, which is well worthy of mention.

Attention may well be drawn at this time to studies on specific features of sewage disposal to indicate its scientific complexity and to emphasize the importance of getting at and considering all of the factors involved. For instance, the New Jersey stations and the New Jersey State Department of Health in preliminary studies of the fauna of the Imhoff tank showed the existance of a relatively stable population composed of the more minute forms of protozoa of which the minute flagellates in dimensions of less than 30 microns were the predominant forms. These fluctuated in numbers somewhat with respect to the acidity of the sewage. Studies by the health department of the Dutch East Indies to determine the duration of life of cholera and typhoid organisms when introduced into several small sized septic tanks showed that, even under the favorable conditions due to high temperature of the locality, the pathogenic organisms always appeared in the effluent from the infected tanks within a few hours after infection. Studies at a well-known tuberculosis sanatorium to determine the frequency with which tubercle bacilli are present in the effluent from a small Imhoff tank receiving the sewage from the institution, showed that the effluent nearly always contained living active tubercle bacilli and that supplementary chlorin treatment was necessary to kill them. Preliminary treatments of the sewage to reduce it completely to liquid form were found necessary. These studies of pathogenic organisms in sewage and small sewage tanks offer considerable food for thought in connection with much of the so-called practical information on small sewage disposal plants which is now available.

With reference to new purification methods, the work of the Argentina Chemical Society on the purification of septic tank effluent with clay or loess silt should be mentioned. Loess silt had a marked influence in reducing the putrescibility of sewage effluent. The reduction of the organic matter increased with the time of contact with the silt up to 4 hours. The amount and degree of pulverization of the silt also had a marked influence. The results are taken to indicate that this influence is mainly over the putrefactive bacteria. Studies at a German engineering experiment station on the use of peat dust in latrine operation and in privy vaults showed that the peat reduced the liquids, gases, and odors.

Obviously the development of sewage disposal methods and apparatus is simplified as the standards of purity required by the grouping of conditions are lowered. This is an important economic consideration which has been emphasized by the works of several of the State boards of health and which shows the advantage of a preliminary analysis and grouping of all factors and conditions involved.

There is plenty of evidence to show that much study is needed of ways and means of securing clean water on farms. With this in view, the U. S. Public Health Service has been studying the principles underlying the movement of Bacillus coli in ground water in relation to the pollution of wells. Natural fecal material from privies was used as the polluting material, B. coli was taken as the bacterial test, and uranin dye was used in tracing the movement of polluted water from trenches to more than 400 experimental wells. The soil was fine sand with an effective size of 0.13 millimeters.

The results showed that pollution with fecal B. coli could be followed in ground water for distances of 3, 6, 10, 15, 25, 35, 45, 50, 55, 60, and 65 feet from the trench in which pollution was placed. In addition, uranin was recovered from these same wells and from wells at distances of 70, 75, 80, 85, 90, 95, 100, 110, and 115 feet from the pollution trench. Pollution traveled these distances within a period of 27 weeks, and only in the direction of the flow of the ground water and in a thin sheet at the surface of the zone of saturation. Even when heavy pollution was recovered at the top, water from lower levels was negative both for uranin and B. coli. All evidence obtained indicated that when the ground water level falls the pollution remains practically stranded in the capillary fringe or in the intermediate belt. It was further found that the progressive movement and the stranding of the pollution are intimately connected with, are dependent upon, and alternate with the rise and fall of the ground water level, and this latter factor is dependent upon the alternation of wet and dry weather. In further studies human feces were buried in pits in a locality of high ground water and covered with sawdust. Of five samples taken three years and two months after burial all were both macroscopically and microscopically recognizable as feces. Three of these samples were positive and two were negative for B. coli. The practical bearing of these results upon the intermittent pollution of wells, the location and protection of water supplies, and the justification for laws forbidding the use of abandoned wells for the disposal of excreta are self-evident.

Studies in India on the purification of water by aerated and bacterized river silt showed that such silt is capable of causing the rapid oxidation of dissolved organic matter in polluted water. Studies by the department of health of the Dutch East Indies showed the effectiveness of so-called autopurification in removing pathogenic organisms from water exposed to the direct rays of the sun. This purifying action is attributed chiefly to the influence of protozoa. The flagellates especially multiplied in such water and destroyed such pathogenic bacteria as cholera, dysentery, and typhoid. This action was more rapid and complete at temperatures of from 29 to 30°C. The Calcutta School of Tropical Medicine has also made important contributions to the knowledge of the bacteriology of small water supplies. The importance of knowing more about the scientific phases of water purification, especially on a small scale, is thus plainly evident.

LAND CLEARING.

While the subject of land clearing has developed rapidly from a miscellaneous matter to one of prime importance, it is yet quite indefinite in nature, and it is difficult in many cases to see wherein the principles of research may be applied. In spite of this, there are at least 13 distinct projects in land clearing at 6 stations in the States of Idaho, Minnesota, California, Oregon, Wisconsin, and Alabama. Most of these projects deal with a comparison of methods of land clearing and with cost determinations and comparisons, and in spite of the nature of the work many are aimed toward rather definite objectives. The work at the Alabama station on the use of explosives in land clearing and the destructive distillation of the stumps to pay the cost of clearing has been mentioned in previous reports. The works at the Idaho and Oregon stations deal specifically with methods such as dynamiting and mechanical pulling. The well-known

works at the Wisconsin and Minnesota stations constitute perhaps the most comprehensive projects on the subject at the stations in that they not only deal with stump and brush removal by various methods, including explosives and machinery, but have involved the development of new types of plows and cultivating machinery adapted specifically to the breaking and cultivation of the cleared land. In the latter connection it has been found at the Wisconsin station that the chief difficulty with brush breaking plows is that roots and brush accumulate under the beam and throw the plow out of the ground. When the beam is offset to the left side of the plow, the accumulation of brush, roots, and trash under the beam is greatly reduced and the space directly in front of and above the plow remains relatively free. Investigations in marsh plowing showed that the 20 inch plow usually requires a 12 to 15 horse-power drawbar rating in the tractor. Tractors weighing from 4,500 to 6,000 pounds operated most satisfactorily in practice, but wheel tractors required that the rear wheels be at least 20 inches wide with angle iron lugs at least 3 inches., and preferably 4 inches wide.

The work at the Oregon station is also quite comprehensive. One of the features of this work has been the development of a new stump burning method adapted to the clearing of big stump land, which involves the use of a furnace, hood, draft pipes, and chimney. By means of these a hole is burned through the base of the stump, and the stump itself is converted into a stove, which with its own draft, chimney, and fuel develops a fire in its interior so intense as to insure its combustion and the firing of the roots. When this is done, the stump is banked in with earth and the crown and roots are burned out below plow depth as a char pit. It has been found that with certain minor exceptions any species of stump of reasonably sound combustible wood or of sufficient size to justify the use of fire, and with roots sufficiently large to carry a fire well, is a desirable subject for the use of the burner. The bigger the stump the better it burns, and the cost of burning has been found to decrease as the diameter of the stump increases. The removal of smaller stumps up to 18 inches in diameter is best accomplished with a puller supplemented with explosives. Only sandy soils were found to be unsatisfactory for the use of this method.

Studies at the California station on the killing of trees and stumps with the Australian arsenical formula, consisting of a mixture of 1 pound of white arsenious oxid, 1 pound of washing soda, and 4 gallons of water, showed that 10 species of eucalyptus were treated with perfect success.

MATERIALS OF CONSTRUCTION.

Materials of construction is a subject which has developed from a minor miscellaneous matter to one of the most important branches of agricultural engineering, and its rise to a position of such importance can be considered as a natural result of the development of agricultural engineering as a whole, owing to its close relation to all other branches of the subject. There is a record of at least 22 projects at 10 stations in the States of Iowa, Montana, Alabama, Minnesota, Pennsylvania, Ohio, Missouri, New York, Wyoming, and Colorado. A great many of these projects have been of a very general and apparently comparative nature.

Some, however, have quite definite objectives which frequently take years to attain. For instance, the work at the Iowa station on the preservative treatment of farm timbers, which has been carried on for 16 years, has shown that the quick growing, nondurable Iowa woods can be successfully used for fence post purposes after having been treated with creosote and that durable fence post woods, such as white cedar, can be made to last for a long period of years with little deterioration after creosote treatment. Results of a similar nature have been obtained by the Missouri and Michigan stations and by the U. S. Department of Agriculture, working in cooperation with several of the State experiment stations. The latter studies have also shown in general that the durability of posts, whether treated or untreated, is influenced by a number of factors, such as species, method of seasoning, size of post, proportion of heartwood to sapwood, shape, and soil and climatic conditions. Radial penetration of a preservative, especially at the ground line, tops, and butts, was found to be of prime importance.

A 9-year study at the Iowa station of over 700 concrete fence posts of different types has indicated that four 0.25 inch square twisted reinforcement rods are necessary to develop maximum strength without the excessive use of steel.

Special attention should be drawn to the work of the U. S. D. A. Forest Products Laboratory at Madison, Wis., on wood as a structural material. Prominent in this are the studies in progress on moisture resistant coatings for wood. These have so far indicated the ineffectiveness of linseed oil in preventing moisture changes in wood, and have shown the superiority in this respect of a bronze coating of a cheap gloss oil and aluminum powder over any other treatment used. Other studies have demonstrated the value of either hot or cold coatings for the prevention of end checks in wood for drying temperatures up to 140°F. and of hot coatings for temperatures up to 170°. No coating is entirely satisfactory above 170°. Still further studies have resulted in basic grading rules and working stresses for structural timbers and standard grading specifications for yard lumber.

Studies at Cornell University on the end bearing strength of wood on surfaces inclined to the fibers indicated the superiority of the Howe formula for the strength of timber obliquely to the grain over the Jacoby formula, and showed that the allowable stress for bearing on the ends of the fibers parallel to the grain should be raised to be commensurate with that used when stresses are perpendicular to the grain.

Studies conducted under the direction of the Franklin Institute on the plasticity of paint have indicated that suspensions made up of white lithopone and pure acid refined linseed oil show the properties of plastic materials even at very low concentrations of the disperse phase. Viscosity is a function of the shearing stress. At high concentrations the relation of yield value to concentration is linear and the material is truly plastic, while at lower concentrations the relation is not linear and the material is considered to be pseudo-plastic.

Studies at the Minnesota station on the effect of organic decomposition products in soils of high vegetable content upon concrete draintile

showed that concrete tile contain free alkali as an inseparable characteristic. This reacts with acid organic compounds from peat soils, producing gelatinous compounds which are soluble in water containing carbon dioxid. Therefore concrete tile as at present made are likely to fail as drainage structures when used in peat soils in the presence of water.

Several other projects of research on concrete have been in operation which are of interest to agricultural engineers. Among these are the studies by the Lewis Institute on stone screenings as fine aggregate for concrete. These showed that good concrete can be made with stone screenings as fine aggregate, but that proper grading to eradicate an excess of dust and extremely coarse particles and the use of not too much water are important factors. Studies on the setting of Portland cement by the British Portland Cement Research Association showed that the time of setting of cement does not change of itself and appears to depend upon the proportion of combined water present in hydrated calcium aluminate or silicate, which tends to form a protective coating around the particles of cement and delay penetration of water to the active core. The greater the quantity of water absorbed by the cement the more impervious is the protective film and the slower is the time of setting. On the other hand, setting is accelerated by any influence which withdraws water from the cement or which attacks, destroys, or modifies the film of hydrated material.

Studies conducted at the University of Michigan on integral waterproofings for concrete showed that insoluble soaps and petroleum residues decreased the absorption of concrete by one-half and showed that hydrated lime and clay cannot be used as waterproofing agents owing to their injurious effect on the strength of the concrete.

The U. S. Bureau of Standards has developed inundation methods for measurements of sand in making concrete and the U. S. Department of Agriculture in cooperation with Purdue University has studies the effect of repeated loads on concrete slabs.

MISCELLANEOUS.

As usual, there are several miscellaneous studies in agricultural engineering which should be mentioned. The record shows about 18 different projects on miscellaneous subjects at 9 stations in the States of Indiana, Illinois, Iowa, Wisconsin, Minnesota, Alabama, Montana, Missouri, and Virginia. These projects include work on soil erosion and its prevention, farm power, harvesting and storage of ice, farm electric plants, and hydroelectric development. Perhaps the most extensive work is that at the Illinois station and at the Iowa station, in cooperation with the committee on animal motors of the American Society of Agricultural Engineers, on different phases of farm power. The studies of the committee on animal power on the absolute pulling powers of mules and horses are well known. Soil erosion and methods for its prevention are commanding considerable attention, particularly in the South Atlantic and Gulf Coast States. It would seem that this subject offers considerable opportunity for fundamental study. Most of the work hitherto undertaken has consisted of comparative tests of terraces of different shapes, sizes, and grades. It is believed that this

work should start with a consideration of the factors governing the erosion of soil by water, the influence of different treatments on these factors and the amount of soil removed by running water under known conditions. With this as a basis, studies could then be intelligently undertaken to develop methods of prevention of erosion. The work at the Missouri station is believed to be more or less typical of such a procedure.

CONCLUSION.

This study of investigational and research work in agricultural engineering during the year has brought out the fact that while there is a marked growth in the research attitude, much is yet to be learned about the best methods of approach to problems for study. The importance of beginning all studies with the factor or thing most vitally concerned is strongly emphasized throughout the work of the year.

More specifically, the work emphasizes the importance of fundamental studies of soil mechanics and hyraulics, of the heating, ventilation, and general housing requirements of farm animals, and of the heating and ventilation requirements and the behavior as regards spoilage under storage conditions of farm crops. Everything indicates that data are required on these subjects to serve as bases for the development of tillage and traction machinery, farm structures, and drainage and irrigation methods and practices.

The conclusion seems inevitable, therefore, that agricultural engineers must broaden and strengthen their cooperative relations with the other branches of agriculture if they expect to maintain a position of equal scientific and professional standing.